GROUP PROJECT 1

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MCEN 4028

"Fiery Fall"

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Background

"The most tangible of all visible mysteries - fire."[1] This quote by Leigh Hunt is the reason our group decided to work with fire and explore the behavior of fire interacting with different materials such as alcohol, WD-40, rubbing alcohol (Isopropyl Alcohol), kerosene, etc. The groups' goals are to create and compare individual images and determine the flame reaction to various stimuli as well as produce aesthetically pleasing images. Since the project incorporates fire, appropriate safety measures were taken to ensure the safety of the group members. The safety precautions will be discussed in the experimental setup section.

My initial idea for a fire image included PVC piping and isopropyl alcohol and is illustrated in Figure 1. I was hoping to create four different sized flames, however, since the isopropyl burned quickly, I had no method of supplying a constant amount of isopropyl alcohol to keep it leveled at the holes. I was unable to keep the flames lit and produce a good image.

Figure 1

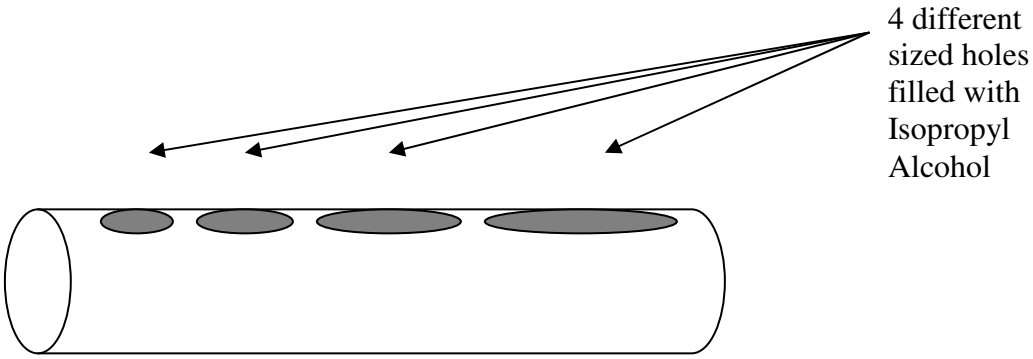

Figure 1: Initial idea for individual image

My final image depicts not only the interaction of fire and isopropyl alcohol but also how fire behaves around a glass's edge. The first question to address involving the physics of fire is the variation of the flame's color. Why are parts of the flame blue and other parts yellow, orange, and red? The second question is what causes the combustion and what determines how it behaves, such as how will the flame initially form and how will it change forms as the flame interacts with the isopropyl alcohol?

Apparatus & Safety Precautions

In order to obtain a pouring fire image, the materials used were Isopropyl Alcohol, Dawn Soap, a metal stand, a metal tray, a lighter, and a ceramic pot. Illustrated in Figure 2 is the experimental setup for this project and in Figure 3 is the glass apparatus used. The glass apparatus sat on a slanted metal tray and was filled with mostly Dawn soap (The Dawn soap played no physical role in creating the flame; the glass could not be completely filled with isopropyl because the glass would become to hot and crack). A thin layer of isopropyl was then poured onto the Dawn soap and since it was slanted, some of it would pour over the side.

Since safety was a top priority, the safety precautions taken included working on cement (garage), with no dry leaves or grass nearby, a bucket of sand, and a gallon of water. A ceramic pot was placed underneath the area where any excess isopropyl might fall. Also, since the inhalation of isopropyl can cause dizziness, headaches, etc., the garage door was cracked and a fan was running (away from the flame) in order to ventilate the air.

Figure 2

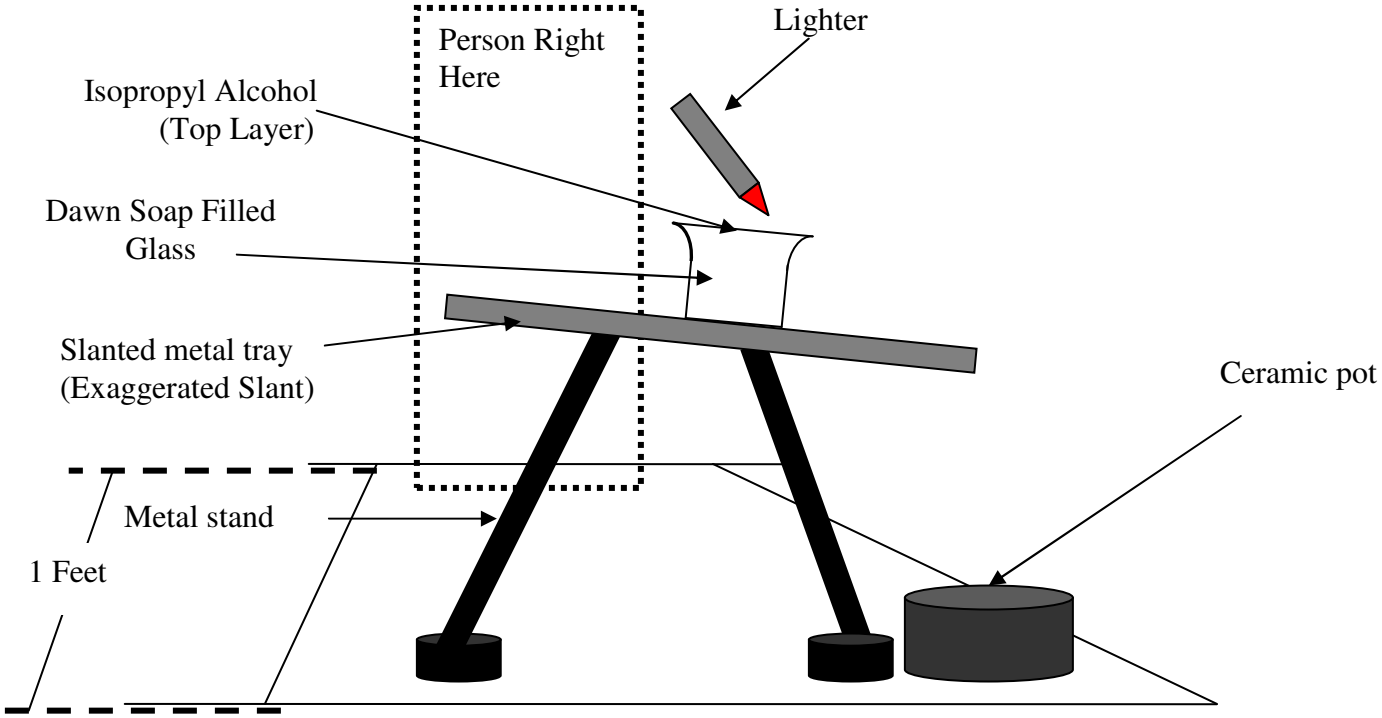

Figure 2: Experimental setup

Figure 3

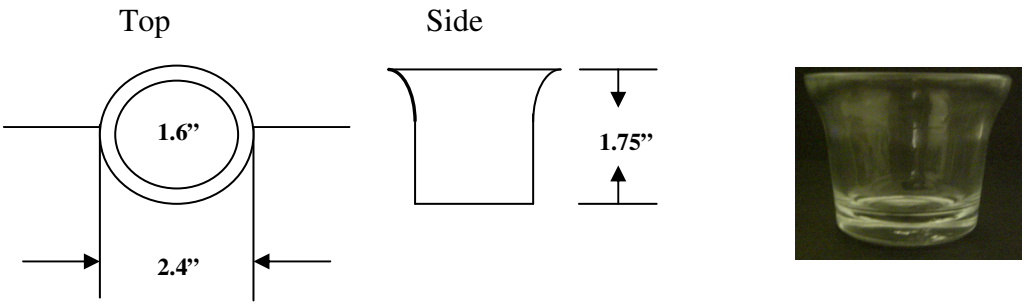

Figure 3: Glass Apparatus

Lighting

Since the garage door was cracked in order to ventilate the garage, the garage door light remained on the entire time. However, this light source was dim, approximately eight feet away, and therefore contributed very little to the image. This light was the only light source (besides the flame itself) and is illustrated in Figure 4.

Figure 4

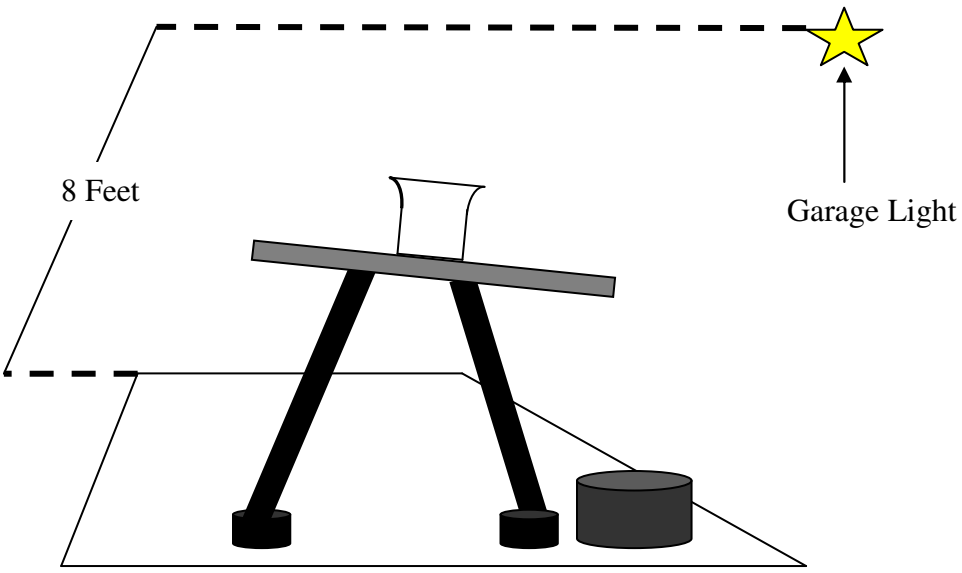

Figure 4: Lighting setup

Science Behind the Image

Rubbing Alcohol is composed of approximately 90-100% of isopropyl alcohol and 0-10% water. For this reason, like most alcohols, this liquid is flammable when combined with heat, flames, strong oxidizers, etc. Combustion is important in understanding the behavior of the flame once the isopropyl alcohol ignites the flame. In order for combustion to occur, heat, fuel, and air must be present. For this image, isopropyl acts as the fuel, the surrounding air provides the fuel's oxygen, and the lighter works as the heat ignition. In many of the "pouring images", parts of the flame appeared to be solid blue with very little color variation. Many are aware that a blue flame represents a hotter temperature than the yellow, orange, and red flames, but what is actually happening that creates these different colors?

This color variation is a result of many factors, which include the presence of soot particles, amount of oxygen supply, air convection, blackbody radiation, etc. To begin, convection occurs when hot, less dense air develops around cooler air and as a result, the hot air rises and spreads out. This hot air appears as our yellow, orange, and red flame and depends on soot and blackbody radiation. Soot is a dark deposit of unburned fuel residues and acts as a good blackbody radiation. Blackbody-radiating soot is more abundant when these is less oxygen because there is not a complete combustion and when this occurs, it creates the yellow, orange, and red color of a flame. However, when there is a greater amount of oxygen, a more efficient combustion can take place and very little soot, if any at all, is produced. It is when very little soot is present and combustion is close to 100% that a blue flame occurs. However, I believe there are other factors playing a role in creating our blue flame around the glass's edge.

The blue flame around the glass's edge is a result of a few different factors. First, there is less isopropyl alcohol along the glass's edge to burn and when the air and isopropyl alcohol mix, it is able to perform a more complete combustion. This results in very little soot and therefore you would not expect to see the yellow, orange, and red color spectrum but instead expect to see blue. Second, as the isopropyl alcohol stays lit on top of the glass, some of the heat is being dispersed among the glass apparatus. As the isopropyl pours down the side of the glass, it has an additional heat source: the glass

itself. This creates a hotter flame, a more combustible flame, and therefore a more blue flame.

As for the flow of the flame, I believe the entire flame is laminar and represents Stokes flow ($R_E<<1$), including the blue flame around the glass's edge. The reason behind this is when looking at the equation, the velocity of the fluid is very close to zero, which means the numerator will be close to zero. The denominator is the absolute viscosity of isopropyl and since this value is not less than 1, we will not have a number close or above 1. Below is a rough estimation of the Reynolds number using an absolute viscosity of 2.43[6], a density of 0.785, a velocity of 0.05m/s, and a length of 0.05 m.

$R_E=(0.785*.05*.1)/2.43$

$R_E=0.0162$

Materials

Listed below are the materials used for the final image. Note that while WD-40 is listed and is seen in the image, it had no effect on the flame and is in the image for more of an artistic reason.

1.) Dawn Soap
2.) Isopropyl Alcohol
3.) WD-40
4.) Lighter
5.) Glass Apparatus

Photographic Technique

Focal Length	6.20 mm
Size of the Field of View	~ 8 inches
Distance from Object to Lens	3 inches

Type of Camera	
Digital	Casio Exilim EX-Z700
Width X Height (Original)	3071 X 2303
Width X Height (Cropped)	2316 X 2304
Exposure Specs	
Shutter Speed	1/25
Aperture	2.6
ISO	800

Final Thoughts

To be completely honest, I did not realize the group project entailed producing individual images and as a result, I waited until we met as a group to prepare a setup and an image. This occurred about a week before the project was due and not completely satisfied with all the images we took as a group, I was limited by time to create my own image.

I would love to redo this project with my original idea of PVC piping and different flammable liquids, perhaps using premixed flames and no premixed flames in order to create a fire color spectrum.

I believe I came up with a good, alternate idea that allowed me to look into the basics of how combustion occurs, why flames have different regions of color, and still create an artistic image. While I would have liked to have created an image in which I had more control of the flow, I am very happy with my final image.

References

1.) http://www.quotegarden.com/fire.html
2.) http://webexhibits.org/causesofcolor
3.) http://www.jtbaker.com/msds/englishhtml/I8840.htm
4.) http://theory.uwinnipeg.ca/mod_tech/node76.html
5.) http://www.shellchemicals.com/chemicals/pdf/solvents/chemical/alcohols/asia/Isopropyl_alcohol.pdf